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NUMERICAL INVESTIGATION ON REFRIGERATION CAPACITY OF COLD STORAGE FOR STORING OF FRUITS AT VARIOUS TEMPERATURES

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ABSTRACT

Storing of fruits in Cold storage is one of the techniques after the post harvest phenomenon. To construct this type of storage system, we must take down the numerous parameters like temperature of supplied food material, quantity to be stored, no of days of storage etc. Freezing is an excellent way to preserve most fresh foods. Freshness and quality at the time of freezing affect the condition of frozen foods (Pilar Cano, M. (1999). If frozen at peak quality, foods emerge tasting better than foods frozen near the end of their useful life. If proper techniques and correct temperatures are used, your foods will keep most of their vitamin content, natural colour, flavour, and texture. Fruits are important sources of vitamin and minerals. They are got rotten before the final consumption due to lack of preservation and storage facilities. This is a useful technique to extend the shelf life and decrease the energy cost. It also helps to improve the sensorial, nutritional and physico chemical properties of foods (Bhardwaj RL, Urvashi Nandal, 2014). In this paper, the refrigeration capacity of plant is examined to maintain various freezing temperatures by considering the quantity of fruits, inside temperature to be maintained, latent of freezing of fruits, heat to be removed in subsequent hours under the mathematical process. This can be achieved and refrigerating capacity of plant is enumerated.

KEYWORDS: Numerical Investigation, Refrigeration Capacity, Cold Storage, Storing of Fruits

INTRODUCTION

Refrigeration is a continued extraction of heat from a body whose temperature is already below the temperature of its surroundings. Fruits are important source of digestible and indigestible minerals, carbohydrates, and certain vitamins, particularly vitamin A and C. (M.C. Giannakourou & P.S. Taoukis (2003) studied the kinetic modelling of vitamin C loss in frozen green vegetables under variable storage conditions. The moisture in most of the fruits is more 75% and fruits are prone to spoilage by molds and yeast. The essential amount of protein, minerals, dietary fibre and calories that provide the nutrimental values are predictable and documented. Freezing is one of the more common processes for the preservation of foods. Although freezing has been recognized as a preservation technique for several hundred years, the major developments in its utilization have occurred only in the 19^{th} century.

It is well known that lowering the temperature reduces the activity of micro organisms and enzymes systems, thus preventing deterioration of the food products. In addition to the influence of temperature reduction on micro organisms and enzymes, crystallization of the water in the product tends to reduce the amount of liquid water in the system and inhibit

microbial growth or enzyme activity in the secondary action.

Fruits and vegetables are mostly water, and thus their properties are close in value to those of water. Initially, all of the heat removed from the products comes from teh exterior of the products, causing a large temperature gradient within the product during fast cooling. But the mass-average temperature, which is the equivalent average tmeprature of teh product at a given time, is used inc alcualtions for simplicity. The heat removed rom the products accounts for the majority of the refrigeration load and is determined form

$Q_{product} = m\, C_p\, (T_{initial} - T_{final}) / \wedge t$

Where $Q_{product}$ is the average rate of heat removed from the fruits and vegetables, m is the total mass, C_p is the average specific heat, $T_{initial}$ and T_{final} are the mass average temperatures of the products before and after cooling, respectively and ^t is the cooling time. The heat of respiration is negligible when the cooling time is less than a few hours. Fresh fruits and vegetables are live products, and they continue to respire at varying rates for days and even weeks after harvesting. During respiration, a sugar like glucose combines with O_2 to produce CO_2 and H_2O. Heat of respiration is released during this exothermic reaction, which adds to the refrigeration load during cooling of fruits and vegetables. The rate of respiration varies strongly with temperature. The heat of respiration of most vegetables decreases with time. The opposite is true for fruits that ripen in storage such as apples and peaches. The initial rates of respiration when calculating the cooling load of fruits and vegetables for the first day or two, and the long term equilibrium rates when calculating the heat load for long time cold storage. The refrigeration load due to respiration is determined from,

$Q_{respiration} = \sum m\, q_{respiration}$

Which is the sum of the mass times the heat or respiration for all the food products stored in the refrigerated space. Fresh fruits and vegetables with the highest rates of respiration are the most perishables and refrigeration is the most effective way to slow down respiration and decay. The primary cooling methods for fruits and vegetables are hydro-cooling, where the products are cooled by immersing them into chilled water; forced air cooling, where the products are cooled by forcing refrigeration air through them; package icing, where the products are cooled by placing cursed ice into the conditioners; and vaccum cooling, where the products are cooled by vaporizing some of the water content of the products under low pressure conditions.

Water freezes when the molecules have slowed down enough to develop bonds upon collision. The rate at which freezing occurs is governed by nucleation and growth. Nucleation is the formation of small solids in a liquid. The clusters of solids are called the nuclei. The rate at which new nuclei form (number of nuclei per second) is the nucleation rate. Once the nuclei have formed, they become the landing sites for other molecules to attach onto. The growth rate is the rate at which the radius of a nucleus grows after formation. The solidification rate is determined by the combination of nucleation and growth rates. The size of crystals formed during solidification is determined by the nucleation/growth processes. A solidification process with fast nucleation rate and/or slow growth rate will result in many small crystals forming. Larger crystals form from slow nucleation rate. Most liquids decrease in volume upon solidification. Water, however, has a rather unique property of expanding during liquid-to-solid transformation. This property comes from the hexagonal structure of ice crystals; water molecules form a hexagonal crystal structure, which actually takes up more volume than if the molecules were freely slipping past one another. Consequently, ice cubes float in water. Freezing consists of lowering the temperature of a food to -18°C or below which crystallizes some of the water and solutes. The preservation of fruits and

vegetables by freezing is one of the most important methods of retaining quality in agricultural products over long-term storage periods. Such products will be safe to eat and nutritious, so long as high-quality raw materials are used, good manufacturing practices are employed and products are kept at temperatures in accordance with current legislation. Frozen foods are not sterile but pathogenic organisms cannot grow at such low temperatures and therefore frozen foods pose no hazard to health provided that they were clean and free from contaminants when frozen. In addition, the fresh qualities of raw vegetables and fruits can be retained for long periods extending well beyond the normal season of most horticultural crops.

Despite the very high qualities of frozen fruits and vegetables now available to the consumer, there will continue to be some competition between fresh and frozen produce. To peel grocer/supermarket-bought carrots in the domestic kitchen has an implication of freshness to the consumer, even though such carrots may have spent many days in transit to the point of sale plus further days on display in the shop, whereas the frozen product was probably processed from roots harvested within 2 days or even sooner. However, some fruits and vegetables cannot be frozen satisfactorily to represent the fresh product, e.g. salad crops such as lettuce and tomatoes, and these, at least for the time being, will continue to be bought and consumed fresh. The two most important factors affecting final product quality in frozen fruits and vegetables are the quality of the raw materials accepted at the factory gate, and the control of temperatures during, and subsequent to, the process. Rarely can the quality of raw material be improved by processing so at best it can only be maintained, and this will depend on the degree of excellence of the processing operations through which it passes. At the factory gate, the processor has the opportunity of accepting or rejecting incoming loads of raw fruits and vegetables. The decision is made after measuring samples from each consignment against a raw-material specification, which should describe precisely what is required and the extent to which the quality may deviate from the ideal before it should be rejected. The ability of a load of raw material to come within specification depends on all that has gone before. The two most important factors affecting raw-material quality are the choice of the right cultivar and the maturity at which the crop is harvested. Other factors will also play a part, such as site, soil type, sowing date, plant population, pest, disease and weed control regime, harvesting method and conditions, handling and transportation.

Rate of Freezing

Freezing produce as quickly as possible can control the extent of cell wall rupture. In rapid freezing, a large number of small ice crystals are formed. These small ice crystals produce less cell wall rupture than slow freezing which produces only a few large ice crystals. This is why some home freezer manuals recommend that the temperature of the freezer be set at the coldest setting several hours before foods will be placed in the freezer. Some freezer manuals tell the location of the coldest shelves in the freezer and suggest placing unfrozen products on these shelves. All freezer manuals give guidelines for the maximum number of cubic feet of unfrozen product, which can be frozen at one time. This is usually 2 to 3 pounds of vegetable to each cubic foot of freezer space per 24 hours. Overloading the freezer with unfrozen products will result in a long, slow freeze and a poor quality product.

Changes Caused by Fluctuating Temperatures

To maintain top quality, frozen fruits and vegetables should be stored at 0° F or lower. This temperature is attainable in separate freezer units and in some combination refrigerator-freezers. A freezer thermometer can help you determine the actual temperature of your freezer. If your freezer has number temperature settings, such as from 1 to 9, check the manual to see what settings are recommended for different uses. Storing frozen foods at temperatures higher than

0° F increases the rate at which deteriorative reactions can take place and can shorten the shelf life of frozen foods. Do not attempt to save energy in your home by raising the temperature of frozen food storage above 0° F. Fluctuating temperatures in the freezer can cause the migration of water vapor from the product to the surface of the container. This defect is sometimes found in commercially frozen foods, which have been improperly handled.

Microbial Growth in the Freezer

The freezing process does not actually destroy the microorganisms, which may be present on fruits and vegetables. While blanching destroys some microorganisms and there is a gradual decline in the number of these microorganisms during freezer storage, sufficient populations are still present to multiply in numbers and cause spoilage of the product when it thaws. For this reason it is necessary to carefully inspect any frozen products which have accidentally thawed by the freezer going off or the freezer door being left open.

Nutrient Value of Frozen Foods

Freezing, when properly done, is the method of food preservation, which may potentially preserve the greatest quantity of nutrients. To maintain top nutritional quality in frozen fruits and vegetables, it is essential to follow directions contained in this leaflet for pre-treatment of the vegetables, to store the frozen product at 0° F and to use it within suggested storage times.

Mathematical Expressions Method

Many food products may be stored at some temperature above the freezing point. The storage may be short-term storage. The storages which are used for short-term storage purposes are known as cold storages. The short-term storage is usually meant for retail establishments where rapid turnover of the products is normally expected. The period for short-term storage ranges from one to two days or to a week or more in some cases, but not more than fifteen days under any circumstances. The long-term storage is usually carried out by wholesalers and commercial storage warehouses. The storage period depends on the type of product stored and its condition on entering the storage. The maximum storage period for long-term storage ranges from seven to ten days for some sensitive products like ripe tomatoes and up to six or eight months for more durable products such as onions and smoked meat. When perishable foods are to be stored for a longer period, they should be frozen and stored in frozen storages. However, some fresh foods like tomatoes are damaged by freezing process and therefore cannot be successfully frozen. In general, the condition required for short-term storage is more flexible than those required for long-term storage and higher storage temperature is permissible for short-term storage. Most of foods for short-term storage are stored at a temperature slightly above their freezing point. The effect of incorrect storage temperature is to lower the quality of the stored product. If the variety of fruits of 2000kg is stored at various temperatures, for that the refrigeration capacity of plant is evaluated for different temperature to maintain the storage. If the refrigeration capacity of the plant is calculated by following data's fruits are supplied to cold storage at 30^0c (T_2) and storage is maintained various temperatures (T_1) at various period of time like -5^0c,-3^0c, -1^0c, 0^0c and 2^0c. In this, expression the latent heat of freezing of fruits is 105 KJ/kg and the specific heat of fruits is 1.256kJ/kg k.

Table 1

S. No	T_2 (^{0}c)	T_1 (^{0}c)	Mass of the Fruits (Kg)	Latent Heat of Freezing (Kj/Kg)	C_p (Kj/Kg K)	Refrigeration Capacity (Tr)
1.	30	-5	2000	105	1.256	2.36
2.	30	-3	2000	105	1.256	2.32
3.	30	-1	2000	105	1.256	2.28
4.	30	0	2000	105	1.256	2.26
5.	30	2	2000	105	1.256	2.22

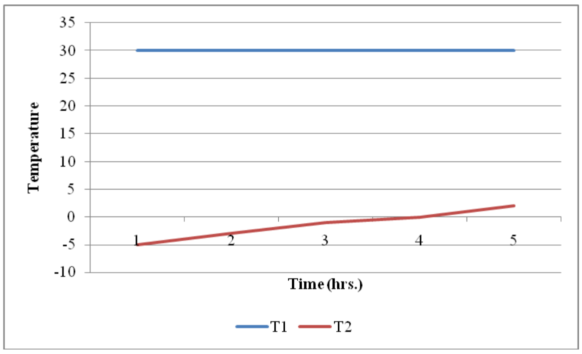

Figure 1: Graphical Representation

Example for Mathematical Expression

$T_2 = 30^0c$

$T_1 = 0^0c$

M = 2000kg

h_{fg} = 105kJ/kg

C_f = 1.256 kJ/kg K

Heat Removed in Fruits in 10hrs

$Q_1 = 2000 \times 1.256(303 – 273)$

Q_1 = 75,360 KJ

Total Latent Heat of Freezing

$Q_2 = m \times h_{fg}$

$= 2000 \times 10^5$

Q_2 = 210,000 KJ

Therefore, total heat removed in 10hrs,

$Q = Q_1 + Q_2$

= 75360 + 210000

= 285360 KJ

Total heat removed in one minute

= 285360 / (10x60)

= 475.6 KJ/min

Refrigeration Capacity of Plant is 475.6/210

= 2.26TR

RESULTS

Thus the refrigeration capacity of plant is enumerated for different storage temperature of fruits. For the short-term storage of fruits, the temperature is slightly above the freezing point. In some, circumstances, the effect of incorrect storage temperature is to lower the quality of stored products. Hence, the perfect relative humidity and air motion are important factors which much be controlled in the storage of all perishable foods in their natural state. The control of these factors is necessary in order to prevent excessive loss of moisture from the product (dehydration). It may be noted that low relative humidity and high air velocity causes excessive dehydration in the stored product.

CONCLUSIONS

The storage life of fully matured or damaged fruits and vegetables is extremely short even under the best storage conditions. In order to assure maximum storage life with minimum loss of quality, the product should be chilled to the storage temperature immediately after harvesting or killing the product. The condition of product at the time of entering the storage is one of the important factors for determining the storage life of refrigerated product. It may be noted that refrigeration only arrests or retards the natural processes of deterioration. But the already deteriorated products cannot be restored to good condition. Hence, only fruits and vegetables in good condition should be accepted for storage.

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